U. S. NAVAL SUBMARINE MEDICAL CENTER

Submarine Base, Groton, Conn.

REPORT NUMBER 537

IN VIVO ASSESSMENT OF THE SOLUBILITY OF TOOTH ENAMEL DURING AN FBM PATROL

by

Dale T. Zorn
Lieutenant, MC, USNR
and
William R. Shiller
Commander, DC, USN

Bureau of Medicine and Surgery, Navy Department
Research Work Unit MR005.19-6024.05

Released by:

Gerald J. Duffner, CAPT MC USN
COMMANDING OFFICER
Submarine Medical Center

24 June 1968

IN VIVO ASSESSMENT OF THE SOLUBILITY OF TOOTH ENAMEL DURING AN FBM PATROL

by

Dale T. Zorn
Lieutenant, MC, USNR

and

William R. Shiller
Commander, DC, USN

SUBMARINE MEDICAL RESEARCH LABORATORY
NAVAL SUBMARINE MEDICAL CENTER REPORT NO. 537

Bureau of Medicine and Surgery, Navy Department
Research Work Unit MR005.19-6024.05

Reviewed and Approved by:

Charles F. Gell

Charles F. Gell, M.D., D.Sc (Med)
SCIENTIFIC DIRECTOR
SubMedResLab

Approved and Released by:

Gerald J. Duffner

Gerald J. Duffner
Captain, MC, U.S. Navy
COMMANDING OFFICER

SUMMARY PAGE

THE PROBLEM

Current preventive dentistry programs are based in part on decreasing the enamel solubility of the teeth. Basic information is needed concerning the longitudinal variations and any environmental and therapeutic effects on this solubility.

FINDINGS

For the subjects evaluated as a whole there were no important mean differences in the enamel solubility during the three test periods. The group of subjects with recent fluoride treatments showed a significant increase in solubility between the first and second periods ($P<.05$). Comparable groups of subjects showed a slight progression in solubility. The differences were significant, however, only between periods one and two for the fluoride group. A high degree of individual variability was noted in the enamel solubility.

APPLICATIONS

The results of this study should be considered merely as indicators for more complete attempts at defining the factors responsible for enamel solubility variations. Follow-up studies could include exploration of the relationship of solubility changes to diet, personal habits, and, of course, atmospheric conditions among others.

ADMINISTRATIVE INFORMATION

This study was conducted in conjunction with the Dental Branch, Submarine Medical Research Laboratory, as a partial fulfillment of requirements for qualification of LT Dale T. Zorn, MC, USNR, as a submarine medical officer.

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit MR005.19-6024—Effect of Stresses of Submarine Service on Oral Health. This report has been designated as Submarine Medical Research Laboratory Report No. 537. It is Report No. 5 on this Work Unit, and was approved for publication as of 18 June 1968.

PUBLISHED BY THE NAVAL SUBMARINE MEDICAL CENTER

ABSTRACT

The solubility of dental enamel is a prime factor in the dental decay process. Conditions which may influence the enamel solubility and the degree of normal variation of this factor are therefore of interest to the Navy Dental Corps.

Enamel solubility was determined in a group of volunteers from the crew of a Polaris submarine. These individuals are exposed continuously for about 70 days in a sealed environment, one known characteristic of which was a higher-than-normal atmospheric concentration of carbon dioxide.

The subjects were selected on the basis of elapsed time since their last topical fluoride treatment. Solubility was determined on the basis of the amount of phosphorus leached from the enamel by a weak acid under standard conditions. Samples were collected at the beginning, middle, and end of the patrol.

No important mean differences were noted in the enamel solubility between the three test periods. Evidently, the FBM environment had little or no effect on enamel solubility. Wide individual variations were noted and are unexplained.

IN VIVO ASSESSMENT OF THE SOLUBILITY OF TOOTH ENAMEL DURING AN FBM PATROL

INTRODUCTION

In recent years the United States Navy Dental Corps has become very interested and active in the field of preventive dentistry. One of the most important advances in this field has been through the program of topical applications of stannous fluoride. The theory that the effects of fluorides on caries are due to the reduction in enamel solubility is the most commonly accepted at present.

The tooth enamel surface is known to react with the ions present in the oral cavity and the application of fluorides makes use of this fact. It is believed that the change in solubility of fluoride-treated enamel results largely from exchange of fluoride for hydroxyl ions within the apatite lattice of the tooth (1).

It has been suggested that the high carbon dioxide (CO_2) content of the tooth environment may play a role in increasing the solubility of enamel (2). This idea naturally focused attention on the FBM environment with its higher than normal atmospheric CO_2. A recent study (3) failed to demonstrate a marked increase secretion of CO_2 by the salivary glands during an FBM* patrol. The possibility still exists, however, of a decreased escape of CO_2 from the fluids of the oral cavity in an environment high in atmospheric carbon dioxide.

The purpose of this study was to evaluate enamel solubility of subjects sealed for seventy days in a closed environment with greater than normal carbon dioxide concentrations. A secondary purpose was to see if there is any relationship of enamel solubility to recent topical fluoride treatments.

MATERIALS AND METHODS

A total of 31 subjects were selected on the basis of topical fluoride experience. All subjects had had fluoride applications in the past, since this treatment is required every six months for all submarine personnel. Approximately one-half of the subjects had received fluoride treatments within two months prior to patrol and one-half had no fluoride treatment within the last six months prior to patrol.

Subjects were tested at the beginning of patrol, middle of patrol, and just before the end of the patrol.

The technique used was a modification of the technique of Morley and Holmes (4). A 30 sq. mm wedge of Whatman 42 filter paper was soaked in .2N acetic acid and was placed on the well cleansed labial surface of a central incisor for one minute. Parenthetically, this concentration of acid is less than that normally present in a lemon or sour pickle. A second dry wedge was used immediately after the first was removed to absorb the fluid still remaining on the tooth. Both samples were placed in a closed plastic container to await analysis at the end of patrol.

Both filter paper discs were ashed in platinum crucibles at 900°C. The ash was then redissolved in 40 ul of .2N acetic acid. Twenty ul of solution was used to perform the phosphorus analysis. Analysis for phosphorus was performed by a micro adaptation of the Fisk and Subbarow technique (5). The results were expressed as total micrograms of phosphorus leached from the tooth under conditions of the study. The amount of phosphorus removed from the enamel is an indication of the solubility of the tooth.

RESULTS

The results from all samples taken are listed below in Table I. Several of the samples from test period one were not available at the time of analysis.

* Fleet Ballistic Missile

Table I — Micrograms of Phosphorus Per Sample

No.	7/67	8/67	9/67
1	3.426	1.728	2.286
2	1.713	2.019	3.426
3	.858	.576	1.143
4	1.428	.864	.570
5	.285	.288	.858
6	.858	4.038	1.143
7	——	2.307	.570
8	——	1.728	2.856
9	——	3.750	2.571
10	——	2.307	3.426
11	——	.864	.858
12	——	2.307	1.428
13	——	2.886	1.143
14	1.143	2.595	.570
15	1.713	2.886	.285
16	.570	2.019	.570
17	2.286	.864	2.001
18	1.428	1.440	2.001
19	.858	1.728	1.143
20	——	2.307	2.856
21	——	1.155	.285
22	.285	1.728	.858
23	2.856	NS	3.426
24	2.001	2.307	2.826
25	2.001	1.440	2.571
26	1.713	2.886	4.287
27	NS	1.440	3.144
28	NS	3.750	2.856
29	NS	3.462	3.426
30	NS	1.155	.858
31	NS	2.595	.570

NS — No Sample

The absolute enamel solubility fluctuates widely. This is evidenced by the low order of correlation noted between values for samples collected at different times for the same men. Parenthetically, a highly significant correlation coefficient of +.80 has been found for similar samples from extracted teeth (6).

Table II — Enamel Solubility During an FBM Patrol (total samples)

Test Period	N	Mean weight of phosphorus removed (micrograms)
1	17	1.50 ± .215*
2	30	2.049 ± .177
3	31	1.834 ± .213

*Standard error of the mean

Table III—Enamel Solubility During an FBM Patrol (matched samples)

Test Period	N	Mean weight of phosphorus removed (micrograms)
1	16	1.41 ± .205*
2	16	1.84 ± .243
3	16	1.66 ± .292

*Standard error of the mean

Table II summarizes the results when the groups are analyzed on the basis of total samples; that is, the test period groups are not completely comparable. There is noted an increased solubility in test periods two and three over test period one, but these differences are not statistically significant.

Table III illustrates the findings when only those men sampled in all three periods were considered. The paired t-test was used and indicates that the differences noted are not statistically significant. A Spearman rank correlation coefficient was computed for the values of test periods two and three, and was not large enough to be considered statistically significant ($r = +.28$).

Table IV — Enamel Solubility Related to Recent Fluoride Therapy (total subjects)

	Period 1	Period 2	Period 3
No fluoride within 6 months prior to patrol	1.68*±.343** (N=9)	2.04±.307 (N=14)	1.71±.266 (N=15)
Fluoride less than 6 months prior to patrol	1.29 ±.22 (N=8)	2.06±.21 (N=16)	1.95±.335 (N=16)

*Mean solubility in ugm phosphorus.
**Standard error of the mean.

Table V — Enamel Solubility Related to Recent Fluoride Therapy (comparable groups)

	N	Period 1	Period 2	Period 3
No fluoride within 6 months prior to patrol	8	1.54±.353	1.73±.438	2.03±.314
Fluoride less within 6 months prior to patrol	8	1.29±.22	1.95±.244	1.72±.533

Table IV illustrates enamel solubility to recent fluoride therapy (total subjects). Table V illustrates enamel solubility to recent fluoride therapy of comparable groups.

The fluoride group in Table IV had a significant increase in solubility between the first and second periods ($P<.05$). When looking at the comparable groups in Table V (8 men with the same fluoride history sampled in each test period) there was a steady progression in solubility. The differences were significant, however, only between test periods one and two for the fluoride group.

DISCUSSION AND CONCLUSIONS

The results recorded from these tests fail to demonstrate any significant changes in enamel solubility which would point to an association with a factor such as CO_2 present in the FBM environment. When comparable groups were considered, in relationship to recent flouride treatment, there was noted a slight increase in solubility between periods one and two. It is doubtful that the interval since fluoride treatment was a significant factor in this group since all subjects had had multiple fluoride treatment during the past few years. Evidently, the FBM environment had little or no effect on the enamel solubility.

It must be concluded that these results do not corroborate the theories resulting from other works done in relating enamel solubility to carbon dioxide concentrations (2, 7). One should keep in mind that the other studies in question to date have been in vitro and were done under anaerobic conditions. It is recognized that many factors in the oral environment other than CO_2 would influence the enamel solubility (8).

Increased enamel solubility remains as one of the most supported theories of the etiology of dental caries. Every effort should be made to delineate wide variations in the enamel solubility. Since the actions of the most successful anti-caries agents lie in reducing this solubility, increased interest should be attached to complete studies of this characteristic.

REFERENCES

1. Hardwick, J. L. The mechanism of flourides in lessening susceptibility to dental caries. Brit. Dent. J. 114:222-228, 1963.
2. Steinman, R. R. The possible role of carbon dioxide in initiating dental caries. J. So. Calif. S. Dent. Assoc. 33:28-31.
3. Hughes, M. R. Salivary CO_2 and electrolyte secretion during exposure to an elevated CO_2 atmosphere. Thesis, submarine qualification, Submarine Med. Center, 1966.
4. Morley, C. W. and Holmes, A. W. In vivo assessment of tooth enamel solubility in acid. Brit. Dent. J. 118:71-76, 1965.
5. Fiske, C. H. and Subbarrow, J. J. Biol. Chem. 66:375, 1925.
6. Shiller, W. R. Unpublished data.
7. Steinman, R. R. The possible chemical reactions between human enamel and carbon dioxide. J. So. Calif. S. Dent. Assoc. 33:434-436.
8. Jenkins, G. N. The influence of environmental fluids on enamel solubility. J. Dent. Res. 45:662-669, 1966.

UNCLASSIFIED

Security Classification

DOCUMENT CONTROL DATA - R & D

(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)

1. ORIGINATING ACTIVITY *(Corporate author)*
U.S.Naval Submarine Medical Center, Submarine Medical Research Laboratory

2a. REPORT SECURITY CLASSIFICATION
Unclassified

2b. GROUP
N/A

3. REPORT TITLE
IN VIVO ASSESSMENT OF SOLUBILITY OF TOOTH ENAMEL DURING AN FBM PATROL

4. OESCRIPTIVE NOTES *(Type of report and inclusive dates)*
Interim report

5. AUTHOR(S) *(First name, middle initial, last name)*
Dale T. ZORN, LT, MC, USNR and William R. SHILLER, CDR, DC, USN

6. REPORT OATE	7a. TOTAL NO. OF PAGES	7b. NO. OF REFS
18 June 1968		8

8a. CONTRACT OR GRANT NO.	9a. ORIGINATOR'S REPORT NUMBER(S)
b. PROJECT NO. MR005.19-6024.05	No. 537
c.	9b. OTHER REPORT NO(S) *(Any other numbers that may be assigned this report)*
d.	

10. DISTRIBUTION STATEMENT
This document has been approved for public release and sale; its distribution is unlimited.

11. SUPPLEMENTARY NOTES	12. SPONSORING MILITARY ACTIVITY
	U.S.Naval Submarine Medical Center Box 600, Naval Submarine Base Groton, Connecticut 06340

13. ABSTRACT

The solubility of dental enamel is a prime factor in the dental decay process. Conditions which may influence the enamel solubility and the degree of normal variation of this factor are therefore of interest to the Navy Dental Corps.

Enamel solubility was determined in a group of volunteers from the crew of a Polaris submarine. These individuals are exposed continuously for about 70 days in a sealed environment, one know characteristic of which is a higher-than-normal atmospheric concentration of carbon dioxide. The subjects were selected on the basis of the time elapsed since their last topical fluoride treatment. Solubility was determined on the basis of the amount of phosphorus leached from the enamel by a weak acid under standard conditions. Samples were collected at the beginning, middle, and end of the patrol.

No important mean differences were noted in the enamel solubility between the three test periods. Evidently the FBM environment had little or no effect on enamel solubility. Wide individual variations were noted and are unexplained.

14. KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Preventive dentistry						
Caries prevention						
Solubility of tooth enamel as factor in dental decay						
Effect of submarine atmosphere on dental health						